April 21, 1959 H. G. WEHE 2,883,257

ELECTRON BEAM RECORDING

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FIG. 1

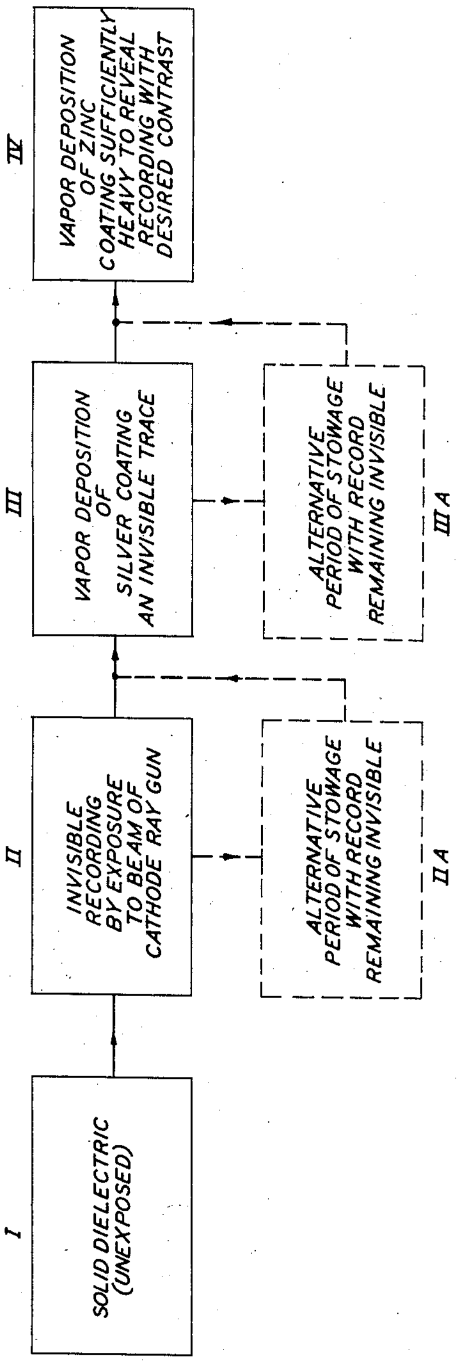

FIG. 2

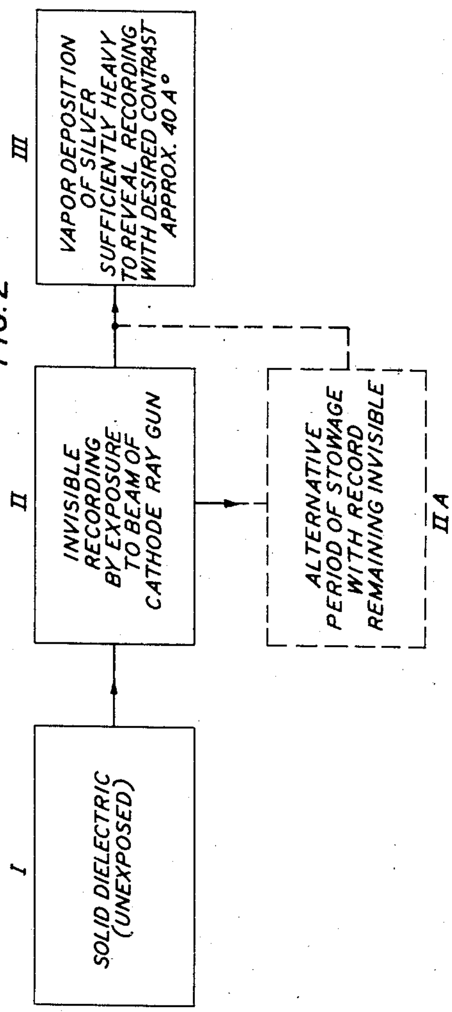

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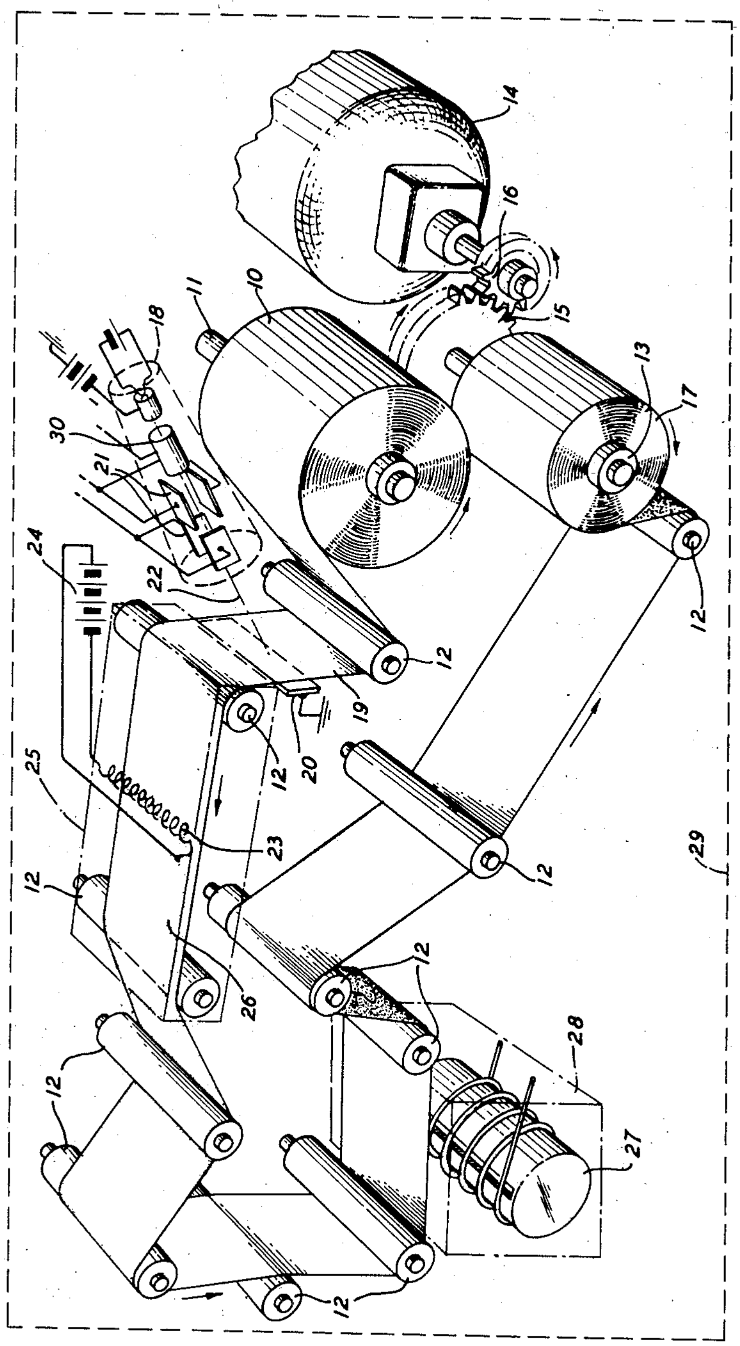
FIG. 3



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United States Patent Office

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ELECTRON BEAM RECORDING

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4 Claims. (Cl. 346—74)

This invention relates to the recording of phenomena or intelligence.

One general object of this invention is to facilitate the translation of transient phenomena into permanent records. Another object of this invention is to enable such translation into invisible records which can be revealed at any desired time, for example substantially concomitantly with the translation or at relatively long times thereafter.

The invention involves broadly converting the phenomena or intelligence to be recorded into radiation representative thereof, directing that radiation upon the surface of a solid dielectric and depositing a film of solid material upon the dielectric.

In accordance with one aspect of the invention, the revelation of the recorded phenomena may be accomplished substantially simultaneously with the incidence of the radiation. The method thus practiced is especially suitable for the television art when utilizing a dielectric in the form of a transparent plastic strip for projecting on a larger scale intelligence received from a distant station. For example, signals may be received, recorded and immediately projected for viewing by large audiences. Additionally the method of this invention enables permanent recording of such television transmissions. It is apaprent that permanent records may similarly be made of a variety of phenomena, for example radar images, oscillograms, intelligence patterns generated by electronic computers and the like.

In another aspect of this invention, the revelation of the recorded phenomena may be delayed for a prolonged period following the radiation step. The method thereby enables latent recordings of intelligence which may be retained in unrevealed form until disclosure is desired. Revelation is then accomplished by the deposition of a solid material as mentioned above. These and other applications will be understood by the exposition of the invention hereinafter set forth.

According to one preferred method, the objects of this invention are realized by employing a dielectric material, such as cellulose nitrate, in the form of a transparent plastic. Where translucence or opacity is desired or where recording medium is too fragile for self support, a supporting medium such as Kraft capacitor paper coated with cellulose nitrate lacquer may be utilized. The recording beam, for example from a cathode ray gun, is impinged upon the dielectric following which solid materials in vaporized form, for example silver and zinc, are deposited successively upon the surface of the dielectric. Typically, the initial film of one material is of such thinness as to be invisible while the succeeding layer of material is heavier and discloses or develops the recorded phenomena. The vapor deposition steps of the process may be advantageously performed within a vacuum.

The methods may be carried out as a continuous process in which the dielectric material in strip form is subjected successively to the above described steps.

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Methods of carrying out the vapor deposition steps suitable for the practice of this invention within a vacuum are described in application Serial No. 316,928 by D. A. McLean and H. G. Wehe, filed October 25, 1952, now Patent No. 2,754,230.

The invention will be more fully understood from the following description taken in connection with the drawing in which:

Fig. 1 is a diagram of one form which the process in accordance with the invention may take;

Fig. 2 is a diagram of another form which the process in accordance with the invention may take; and

Fig. 3 is a perspective schematic view of illustrative apparatus for practising the methods in accordance with this invention.

Referring to Fig. 1, the recording process begins with the dielectric material in dry unexposed form. In addition to cellulose nitrate previously mentioned, other dielectric materials may be employed. For example, other organic solids such as cellulose acetate, cellulose acetate butyrate, polystyrene, polyethylene terephthalate, ethylcellulose, and regenerated cellulose have been found satisfactory. These dielectric materials, including cellulose nitrate, are obtainable as transparent plastics, a particularly useful form for practicing the method of this invention. Additionally, recording may be accomplished in dielectric lacquers coated on supporting dielectric materials. For example, lacquers composed of any one of the compounds; cellulose nitrate, cellulose acetate, cellulose acetate butyrate, or polystyrene, in solution, coated on dielectric paper and thoroughly dried are susceptible to the recording method herein described.

As depicted in Fig. 3, the dielectric may be utilized advantageously in strip form gathered in a roll **10** which may be fed continuously from a mandrel **11** and passed over a series of rolls **12** to a final winding mandrel **13** driven by an electric motor **14** through gears **15** and **16**. The record-bearing material is thus gathered in a roll **17** on the mandrel **13**.

Step II comprises the recording of the desired phenomena and as illustrated in Fig. 3 may be accomplished by directing the beam from a cathode ray gun **18** upon the dielectric strip **19** and the backing plate **20** juxtapositioned thereto.

In the apparatus, the phenomena to be recorded exist in the form of or are converted into an electrical signal which is applied to the deflection plates **21** or control electrode **30**, or both of the cathode ray gun **18**. The emission of the energized gun forms a beam which impinges upon the surface of the dielectric. As is well known in the art, the signal impressed upon the control and deflecting electrodes is determinative of the form and intensity of the pattern traced upon the target surface. Thus the trace upon the dielectric surface corresponds in instantaneous position to one parameter of the signal as represented by the potential or potentials applied between the deflection plates. The intensity of the beam may be controlled in accordance with another parameter of the signal as represented by a voltage applied to the control electrode.

Where the recorded trace consists merely of a continuous curvilinear figure representing functions of time and amplitude, only one set of deflecting electrodes need be used if the dielectric strip is moved at uniform speed. Where complete images are recorded as in the television art, complete beam control may be utilized and the dielectric material momentarily remains stationary for the period during which a complete image is traced or the motion of the dielectric may be substituted for one sweep parameter. The recorded trace is invisible at this juncture. The backing plate **20** functions as a target or collecting plate for the beam.

The process is continued in step III during which the dielectric material is coated advantageously with a film of extreme thinness as by vapor deposition from an energized molybdenum filament loaded with silver. This film is of such thinness as to be invisible, say less than ten angstroms. Considering the dielectric surface generally, this initially deposited film is approximately of the order of magnitude of a monolayer. As depicted in Fig. 3, the filament **23** is heated by the battery **24** causing the silver to vaporize from which condition it deposits selectively upon the strip **26**. In the method of Fig. 1 the deposited silver is invisible.

The enclosure **25** indicated in dotted outline provides a mask which prevents dissipation of the silver vapor which otherwise would coat the entire apparatus. This silver deposition step may be carried out over an area of the strip which is simultaneously being subjected to the impingement of the electron beam.

As represented herein, deposition of the solid material occurs on the same surface previously or simultaneously subjected to the electron beam. However, phenomena have been recorded on dielectrics of the lacquered paper group by simultaneously or subsequently depositing the solid material upon the reverse surface from that subjected to the recording beam. Advantageously, the radiation is impinged upon the lacquered side of the coated paper dielectrics. Where the above-noted reverse plating method is used, recordings have been made with the paper surfaces interchanged; that is, in one case irradiating the lacquered surface and plating the paper surface, and in the other irradiating the paper surface and plating the lacquered surface.

The succeeding step denoted is IV in Fig. 1 comprises the vapor deposition of a heavier layer of coating material directly upon the initially deposited film. This revealing layer may be from 50 to 1,000 angstroms thick depending upon the desired degree of contrast. This is accomplished by passing the dielectric strip near the coil-heated crucible **27** filled with zinc. As in the case of the silver deposition apparatus, the zinc vaporizing equipment is masked by an enclosure **28**. Alternatively, in the case of the method of Fig. 2, the heavier layer of coating material may consist of additional silver deposited from the loaded molybdenum filament omitting the zinc deposition step. By subjecting the dielectric material to the silver vapor until the deposited layer has a thickness of the order of 40 angstroms or more, the recorded phenomena will be revealed therein without the deposition of a separate layer of different material such as zinc. A generally more advantageous control of results is attained by the utilization of different materials in the successive layers. Generally, better images are obtained also in the case of the opaque dielectrics where both beam impingement and vapor deposition occur on the lacquered side.

It is to be noted generally that the form of apparatus herein described for accomplishing the method of this invention is particularly suitable where immediate projection of the recorded phenomena is desired. Deposition of the initial film, step III, may occur simultaneously with the radiation step, the moving dielectric strip passing rapidly on to receive the heavier layer which reveals the recorded image. Where the dielectric strip is a transparent plastic such image may be immediately projected by conventional and well-known methods. Also projection may be by reflection from an opaque surface.

It is to be understood that certain modes of radiation should be carried out within an evacuated space. For example, the electron beam recording step of the specific method herein described should occur within a vacuum.

Other radiation methods may be used to record phenomena under atmospheric conditions (in a vacuum, or at greater than atmospheric pressure). For example, ultra-violet light in beam or flood form will enable recording. Where ultra-violet flood lighting is employed the dielectric is masked to produce the desired recorded image. Ion beams likewise lend themselves to radiation recording in air at normal pressure. Generally, ultra-violet and ion recording is not as rapid as electron beam recording.

A vacuum envelope **29** is indicated as enclosing the entire apparatus of Fig. 3. Within such envelope maintenance of maximum absolute pressure of the order of 1×10^{-4} mm. of mercury has been found advantageous. Where such an atmospheric control enclosure is provided, it is possible also to affect the degree of background plating by utilizing pure gases such as hydrogen and oxygen in place of residual air. For example, where electron beam recording is carried out using capacitor paper coated with cellulose acetate lacquer, a hydrogen atmosphere retards plating in the image developed by silver and zinc deposition. Conversely a residual oxygen atmosphere enhances plating with the same materials.

Blocks IIA and IIIA of Fig. 1 and block IIA of Fig. 2 indicate alternative procedures by which the dielectric material may be temporarily withdrawn from the process before revelation of the recording. Whether this interruption of the process occurs at IIA or IIIA, the recorded phenomena are invisible. Withdrawal at IIIA, however, following the thin layer coating presents the greater desirability from the standpoint of stability of the recorded matter.

The underlying reason for the above-described process has not been fully established. It is established, however, that the radiation to which the dielectric is subjected so affects the dielectric as to cause the initially deposited film of material to adhere only in certain areas in accordance with the radiation pattern.

Why the initial invisible film deposits sometimes more heavily over the irradiated and sometimes over the non-irradiated areas of the dielectric is not known exactly. Generally, however, in the case of electron beam recording the appearance of the image may be varied by varying the thickness of the initial film within the limits of invisibility. For example, using cellulose acetate and cellulose acetate butyrate for recording, the beam trace as finally revealed by zinc deposition is dark on a light background (viewed with transmitted light) when a small amount of silver is used. Increasing the amount of silver causes the trace to appear light on a dark background. Such reversal effect does not occur when the dielectric is cellulose nitrate upon which the beam trace is constantly light on a dark background. Irrespective of material and amount of deposition, the shading of the recorded phenomena is also a function of the recording beam intensity as has been noted above. The use of silver and zinc as deposition material results in recordings having the general black-and-white appearance of photographic negatives and positives.

The readiness with which the dielectric accepts the initially-deposited material may be termed the accommodation coefficient of the dielectric. The recording radiation then may be considered as producing a modification of the accommodation coefficient in accordance with the phenomena being recorded. This modification then leads to the difference in the deposition or sticking rate of the initial layer of material.

Indications are that the initial film which is ordinarily invisible furnishes the nuclei or seeds upon which the heavier revealing coating grows, in a manner somewhat analogous to the initiation of crystal growth in a supersaturated solution. Hence, the materials of which the coating films may be composed are defined in some degree by the functions which they perform.

In a broad aspect, therefore, the deposited coatings may be composed of normally solid materials which may be vaporized without suffering consequent decomposition. Generally, the initial film may be composed of materials which recognize the modified accommodation coefficient of the dielectric and will deposit differentially in accordance thereto. Such initial film materials also provide the seeds or nuclei for the succeeding layer and hence are said to have the property of easy nucleation. Silver and copper are representative of satisfactory initial film materials.

Because the revelation of the recorded phenomena in the heavier coating appears to result from the adherence of the particles of this layer to the seeds or nuclei of the initial layer they should have poor nucleation properties. In other words, materials used for the revealing coating should not deposit well on the untreated dielectric from a low vapor concentration. Zinc and cadmium are representative of materials fulfilling the requirements for heavier coating materials.

While the above is believed to be a correct explanation of certain principles underlying applicant's invention it is to be understood, of course, that the invention is independent of any theory which may be advanced to account for the results obtained.

Desirable results have been obtained using a cathode ray gun of the electrostatic deflection type with the cathode positioned about five inches from the recording surface with the backing plate one-half inch behind the dielectric strip. Under such conditions it has been found advantageous to utilize a grounded backing plate with the cathode of the gun at high negative potential, say of the order of 700 volts, while the plating machinery is maintained at positive potential. Recording may be facilitated for certain purposes by employing different velocities for the strip in its travel through the apparatus. Such velocities may range from zero velocity to greater than 800 feet per minute.

It is to be understood that the above-described arrangements are illustrative of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of recording phenomena which comprises projecting an electron beam against a surface of a thin sheet of dielectric selected from the group consisting of cellulose nitrate, cellulose acetate, cellulose acetate butyrate, polystyrene, polyethylene terephthalate, ethylcellulose, and regenerated cellulose, varying the point of incidence of said beam in accordance with a parameter of said phenomena, placing said sheet of dielectric in storage for a period of time, removing said sheet of dielectric from storage, vapor depositing an invisible film of metal selected from the group consisting of silver and copper on said dielectric surface, and applying by vapor deposition on said film a visible permanent coating of a metal selected from the group consisting of zinc and cadmium.

2. The method of recording phenomena which comprises projecting an electron beam against a surface of a thin sheet of dielectric selected from the group consisting of cellulose nitrate, cellulose acetate, cellulose acetate butyrate, polystyrene, polyethylene terephthalate, ethylcellulose, and regenerated cellulose, varying the point of incidence of said beam in accordance with a parameter of said phenomena, vapor depositing an invisible film of metal selected from the group consisting of silver and copper on said dielectric surface, placing said sheet of dielectric in storage for a period of time, removing said sheet of dielectric from storage, and applying by vapor deposition on said film a visible permanent coating of a metal selected from the group consisting of zinc and cadmium.

3. An apparatus for making a visual record for phenomena comprising, in combination, a sheet of dielectric material, means for projecting radiation representative of said phenomena upon said sheet, said projecting means comprising an electron gun, first means for vapor depositing on said dielectric sheet an invisible film of a metal selected from the group consisting of silver and copper, and second means separated from said first means for vapor depositing a coating of a metal selected from the group consisting of zinc and cadmium upon said dielectric sheet, and means comprising at least one motor-driven roller for moving said dielectric sheet successively past said projecting means, said first vapor depositing means, and said second vapor depositing means.

4. Apparatus in accordance with claim 3 in which said sheet of dielectric material is one selected from the group consisting of cellulose nitrate, cellulose acetate, cellulose acetate butyrate, polystyrene, polyethylene terephthalate, ethyl-cellulose, and regenerated cellulose.

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